REMARKS/ARGUMENTS

Claims 1-18 and 31-36 are in the application. Claims 1, 2, and 12 are in independent form. Claims 2 and 4-8 are indicated allowable if rewritten into independent form.

Restriction Requirement

Applicant affirms the election of the invention of the method of making, claims 1-18 and cancels claims 19-30.

Claim Objections

Claims 17 and 18 stand objected to for indefiniteness. The amendment to claims 17 and 18 correct the indefiniteness problem.

Claims 2 and 4-8 stand objected to as being dependent on a rejected base claim. Claim 2 is rewritten into independent form. Applicants thank the Examiner for the indication of allowable subject matter,

Rejections Under 35 USC 102(b)

Claims 1, 3, and 9-18 stand rejected under 35 USC 102(b) as being anticipated by US Pat. No. 5,083,033 to Komano et al. ("Komano").

Amended claims 1 and 12 recite depositing a high resistivity conductive material. Komano teaches the deposition of an insulator. Col. 2, lines 8-14; col. 4, lines 58-68. Increasing conductivity would be contrary to the purpose of Komano, who's goal is to provide an insulating layer to isolate conductors. Komano does not teach how to deposit a high resistivity conductive material.

The examiner states that the material deposited by Komano has a resistance of 1 megaohm

or greater, citing col. 4, lines 64-67. The cited passages refer to the volume resistivity, measured in ohm-cm. The resistivity values in applicants' claims are sheet resistivity, measured in ohms per square. Attached is a printout of a web page (http://four-point-probes.com/ohms-cm.html) that explains the difference between the two measurements. Considering the thinness of the deposited layers, the difference between one megaohm per square and one megaohm-cm is several orders of magnitude. The different measurements reflect the different functions of the deposited materials.

The pending claims are now substantially the same as the claims in applicants' corresponding PCT application, PCT/US02/02075, which claims were indicated as being novel and inventive by the USPTO as International Preliminary Examining Authority.

Applicants submit that all claims are now allowable and respectfully requests reconsideration and allowance of the application.

Respectfully submitted,

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Four-Point-Probes

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How to Calculate Ohms-cm (volume resistivity) from Ohms-per-square (sheet resistance)

by John Clark, C. Eng, M.I.Mech.E., F.B.H.I., Managing Director of Jandel Engineering Ltd.

The term Ohms-cm (Ohms centimeter) refers to the measurement of the "bulk" or "volume" resistivity of a semi-conductive material. Ohms-cm is used for measuring the conductivity of a three dimensional material such as a silicon ingot or a thick layer of a material. The term "Ohms-per-square" is used when measuring sheet resistance, i.e., the resistance value of a thin layer of a semi-conductive material. This article briefly explains the relationship between Ohms-cm and Ohms-per-square, and how to convert from Ohms-per-square to Ohms-cm. To calculate Ohms-cm using the Jandel Resistivity Test Unit, **one needs to know the thickness of the wafer** (if it is a homogeneous material) **or the thickness of the top layer that's being measured**, to be able to calculate Ohms-cm.

> The equations for calculating bulk resistivity are different from those used to calculate sheet resistance, however, if one already knows the sheet resistance, bulk resistivity can be calculated by multiplying the sheet resistance in Ohms-per-square by the thickness of the material in centimeters.

Q.At what point do you stop multiplying the sheet resistance by the thickness in centimeters to arrive at Ohms-cm?
A. When the thickness exceeds 0.1 of the spacing between two needles - after which sheet resistance doesn't apply. So, 0.1mm for a probe head with 1mm needle spacings. However, due to corrections, up to 0.3mm would be ok.

If the thickness is equal or greater than five times the probe spacing, the correction factor to be applied to the formula resistivity(rho) = 2 x pi x s x V/I is less than 0.1%

From the sheet resistivity point of view, the correction factor tables we have start at ratio thickness to probe spacing of 0.3, where the correction factor is unity, to a ratio of 2, where the correction factor is x0.6337. I expect these tables can be extended up to a larger ratio, but clearly from a thickness of 2x spacing up to 5 x spacing is a bit of a no-mans land, but if one assumes that the situation is 'bulk' there are correction factors covering the ratio of thickness to spacing from 10 down to 0.4 where the correction factor is x0.288.

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What is the range of bulk resistivity (Ohms-cm) that the Jandel Resistivity Test Unit can measure Ohms-cm
This crops up regularly, and it is hard to answer - let me give you an example to show the problem.

The normal range of sheet resistance which the Jandel Resistivity Test Unit can measure lies between 1 and 10^7 ohms per square. The volume resistivity would be numerically equal to the sheet resistance if the specimen was 1 cm thick and made from the same material from which the sheet resistance figure was derived. It is difficult to define the limits of volume resistivity that the RTU can measure - for example we could not measure the volum resistivity of a block of platinum 1 cm thick because it is too highly conducting for the RTU to obtain a reading. If it was a platinum film 200 Angstroms thick then we could measure the sheet resistance easily and it would be approx 100 ohms per square.

Let's consider a specific wafer sample:

Let us assume that the wafer is 0.5mm thick and its resistivity is 0.005 Ohms-cm. We can set the RTU to deliver 4.5324 mA so the mV displayed is numerically equal to the sheet resistance in ohms/square. In this situation we can say that:

bulk resistivity = sheet resistance x thickness in cm.

$$\text{i.e., } 0.005 = \frac{4.5324 \times 0.05\text{cm} \times (\text{mV})}{4.5324}$$

$$= \frac{0.005}{0.05} = 0.10\text{mV}$$

This would be the displayed reading.

Of course, if it was a thin film, the thickness would be much less than 0.5mm and the sheet resistance correspondingly more so it would be possible to calculate the bulk resistivity more accurately. It is the eternal problem of low resistivity materials, where a supplementary voltmeter able to read a microvolt or less, is desirable. Such a voltmeter would be useful for the 0.005 Ohm-cm material -essential if it was thicker than 0.5mm.

If we were to assume that we were talking about the **bulk resistivity of silicon wafers**, then, using the formula rest=2 x pi x s x V/I we calculate that with a probe tip spacing of 1.00mm, V=2V, I=10 nanoamperes the **MAXIMUM value of resistivity would be about 10^8 ohm.cm**. Using V=10 x 10^-6V and I=10x10^-3 amperes the **MINIMUM value would be about 6 x 10^-4 ohm.cm**. There are limitations on these values - in practice it may not be possible to drive the minimum current in the high resistivity material owing to contact resistance, and equally for the low resistivity material we are only looking at a single digit at the end of the voltage display. So we quote something a little less ambitious say 10^-2 up to 10^6 ohms.cm.

The equation for calculating Ohms-cm **without** converting from sheet resistance is:

$$2 \times s \times PI(\pi) \times V/I$$

Where s is the spacing between each of the four point probe tips in cm. If one uses a probe head with tip spacing of 1.591mm (62.6 mils), since 1.591mm is 1/(2 x pi)cm, it cancels out to V/I

Four-Point-Probes is a division of Bridge Technology. To request further information please call Bridge Technology at (480) 988-2256 or send e-mail to Larry Bridge at: sales@bridgetec.com

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